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THE SINGING INSECTS OF KING'S PARK AND PERTH GARDENS

By DARRYL T. GWYNNE, PAUL YEOH and ANDREA SCHATRAL,
Department of Zoology, University of Western Australia,
Nedlands, Western Australia 6009

INTRODUCTION

Certain groups of insects are well-known for their contributions to the cacophony of animal sounds that can be heard in nature. The most prominent of insect sounds are produced by three major groups: cicadas (order, Hemiptera: family, Cicadidae), crickets and katydids[1] (Orthoptera: Gryllidae and Tettigoniidae, respectively), and grasshoppers and locusts (Orthoptera: Acrididae). These groups comprise the "singing insects" since most species are acoustical. However, occasional species in other insect orders have also evolved the ability to produce distinct sounds.

The function of sounds

The sounds produced by these insects appear to function almost exclusively in a reproductive context. Alexander (1967) classified the songs of arthropods into several types. Most of the prominent insect sounds are the distinct "calling songs" produced by males. In most species the silent female is attracted to the calling male. This was first shown by the Italian naturalist Brunelli who caged a calling male of the European katydid, *Tettigonia viridissima*, on one side of his garden and observed how females released on the opposite side of the garden hopped immediately toward the male. However, it was the pioneering experiments of Regen (1912) who, using a microphone-telephone system, demonstrated that sound was the stimulus that attracted female crickets to calling males. Russell et al. (1831), who cited Brunelli's studies, concluded that sounds "are intended as signals for their companions." This is in contrast with the conclusion of a later student of singing insects, H.A. Allard (1929), who, because he saw little evidence in nature of females being attracted to males,

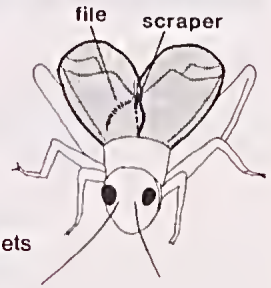

Figure 1A: **A calling male** *Eurygryllodes* (redrawn from Fig. 24), showing the position of the file on the underside of the cricket's right wing and the scraper on the leading edge of the left wing.

Figure 1A and 1B: Sound-producing organs of crickets and katydids.

[1]Called bushcrickets in Great Britain and Europe.

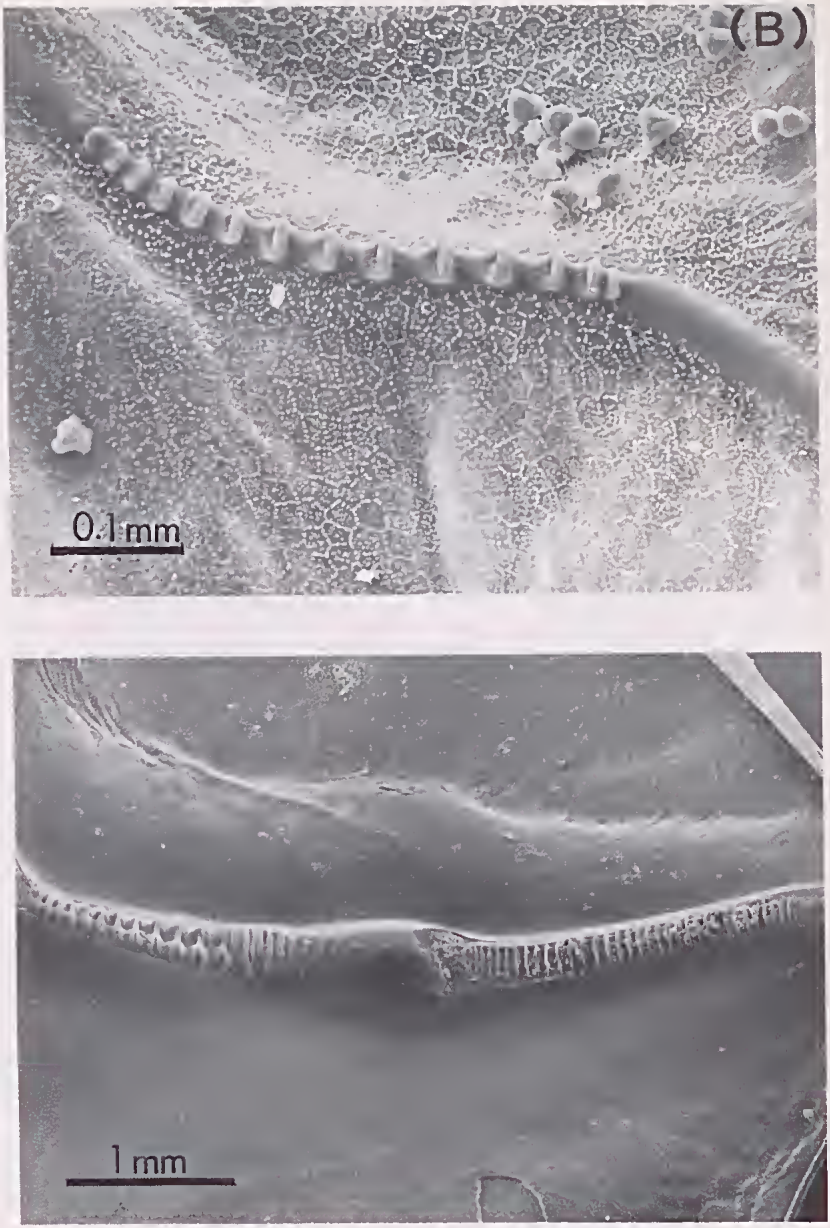

Figure 1B:
Underside of the forewings of katydids showing the stridulatory file: top, the zaprochiline species (see Fig. 7); bottom, *Tympanophora similis* (see Fig. 13).

was misled into concluding that "the theory ascribing sound to sex in insects has probably been much overdone." He suggested instead that "they love sound" and "find it a means of self-expression"!

In a few species of singing insects females do not move to calling males but instead answer the male with a short burst of sound which elicits movement toward the female by the male. This sort of pair-forming system has been observed in grasshoppers, katydids of the subfamily Phaneropterinae (Otte, 1977), and a Western Australian cicada (Gwynne, 1987).

Alexander (1967) also defined a class of sexual signals called "courtship sounds". These are produced by the male only after the sexes have made physical contact. Although rare in katydids, courtship sounds commonly form part of the sexual behaviour after pair formation in crickets, grasshoppers and cicadas.

Sound-producing mechanisms

Two main mechanisms are used by the singing insects to produce sounds: in frictional mechanisms a roughened structure is rubbed over another part of the body; and in vibrational mechanisms a pair of membranes are vibrated using direct muscle attachments (Chapman, 1982). The sound-producing organ of a cricket or katydid is a frictional mechanism consisting of the file — a row of teeth on a thickened vein on the underside of one forewing — over which is rubbed the scraper — a thickened ridge on the top of the leading edge of the opposite forewing (Fig. 1). Each forewing has both a file and a scraper but usually only one file-scraper pair is functional. Many katydids and crickets have lost the ability to fly yet retain their forewings as sound-producing organs. The movement of the file over the scraper causes part of the forewing to vibrate at a particular pitch or frequency. In crickets the resonating structure tends to be tuned so that the pitch of the song is narrow and close to a pure tone. In contrast, katydid forewings usually vibrate at a number of different frequencies and this produces a "noisy" or "broad-band" song. Grasshopper sounds are also broad in frequency range. Most grasshoppers produce sound with a file and scraper mechanism on the hind femur and the front wing. In some species sounds are produced by buckling the wing while in flight.

Male cicadas call by directly vibrating membranes. The membranes are a pair of tymbals on the first abdominal segment. The tymbals are attached by a thin piece of cuticle to a pair of large muscles which contract to operate the sound-producing mechanism. Air sacs associated with the tymbals resonate during sound production (Fig. 2). Female cicadas do not possess these

Figure 2A and 2B: Sound producing organs of cicadas.

(A)

Figure 2A: Dorsal view of the abdomen of a tick tock (*Cicadetta quadricincta*) showing the varied tymbals.

(B)

Figure 2B: Transverse section of the first abdominal segment of a cicada showing the sound producing organs. B is redrawn from Pringle (1954) and Chapman (1982).

structures. In the species in which the female produces a sound in response to the male call she does so by flicking her wings (Gwynne, 1987).

The most common sound-producing mechanism observed in other groups of acoustical insects and arthropods is the file-and-scraper. This frictional mechanism has evolved a number of different times as it is located on different areas of the body in different species.

The evolution of insect calling songs

Although calling insects use a variety of frequencies and song patterns, within-species variation in song is not great. Thus, the songs represent a character useful in distinguishing different species. The species-specificity of calls was at one time thought to have evolved to prevent females from pairing or mating with the wrong species (e.g. Alexander, 1960). However, there is little evidence to support this as a general argument (Walker, 1974; West Eberhard, 1984). This, plus the fact that specific song characters, and female response to these characters, are expected to evolve as a result of other sorts of natural selection on signalling systems (West Eberhard, 1984), suggests that songs have rarely evolved to advertize species identity.

STUDY SITES AND METHODS

The study site

King's Park is an enclave of bushland of approximately 1,000 acres bordered by the Swan River on the south and east and by the metropolitan city of Perth on the north and west. The bushland is similar to the original vegetation which was found in the Perth area prior to colonial settlement (Tingay and Tingay, 1982). The native vegetation of the park (see Main and Carrigy, 1953; Main, Serventy et al., 1957) comprises two main areas, one dominated by *Banksia* and Jarrah (*Eucalyptus marginata*) trees and the other by Tuart (*E. gomphocephala*). The Tuart area is associated with a raised limestone ridge (Mount Eliza) which overlooks the Swan River. The Jarrah- *Banksia* formation makes up most of the park. The main native trees of this area are Jarrah, *Banksia attenuata, B. menziesii* and she-oak, *Casuarina fraseriana*. Common bushes are *Jacksonia furcellata, Acacia cyanophylla, Macrozamia reidlei* (zamia 'palm') and *Xanthorrhoea preissii* (the blackboy).

Study methods

Censuses of the calling activity of different species were conducted by following fixed routes along the paths and firebreaks once every 7-9 days. Census routes were selected so that they passed through a variety of different vegetation types including *Banksia* woodland, dense copses of *Casuarina* and regenerated vegetation in an area that had been burnt the previous year. The calling crickets and katydids (and other nocturnal species) were censused at night by walking a route of approx. 1300 metres through the southern part of the park, a half to one hour after sunset. This census was conducted from September 1, 1985 to August 31, 1986. A "Mini" bat-detector (QMC Instruments, London) was used during the census to scan the vegetation. This device detects ultrasound and thus picked up the calls of katydids whose songs have ultrasonic components.

The diurnally-active cicadas were censused from November 1, 1986 to May 20, 1987 by walking or running along a route of approx. 5,100 metres in mid afternoon (1500-1600 h).

The songs of most species were recorded using a Nagra IV SJ or a Racal tape recorder and a ¼ or ½ inch diameter Brûel & Kjaer condenser microphone. Song patterns were obtained from an X-Y plotter connected to a Norland Processing Oscilloscope and redrawn to form the figures presented below.

Specimens of Orthoptera were identified by Dr. D.C.F. Rentz, CSIRO, Canberra; cicadas by Mr. M.S. Moulds, Entomology Department, Australian Museum, Sydney; the singing spider by Dr. V. Davies, Queensland Museum, Brisbane; and the singing moth by Mr. E.D. Edwards, CSIRO, Canberra. Voucher specimens have been placed in the collections of the investigators' respective institutions. Some of the katydids and cicadas turned out to be undescribed genera or species. Australian National Insect Collection numbers and the numbering system of Mr. Moulds are used to identify these species.

SINGING INSECTS IN KING'S PARK AND PERTH

Most species of singing insects are found in the natural bushland of King's Park. Only a few of these species occur in and around Perth gardens. In this section we refer to the insects of the park unless otherwise stated. In the park the dominant group of calling insects are the katydids (16 species) and cicadas (5 species). Only three singing crickets and two grasshoppers have been noted. This contrasts with other singing insect faunas where the latter two groups are usually as diverse as cicadas and katydids (e.g. Alexander et al. 1972).

Typically the songs of insects can be distinguished from those of vertebrates in that insect sounds lack the modulation in pitch or frequency that is typical of bird song and, in general, are higher and broader in pitch (frequency spectra) than the calls of birds or frogs. Most insect sounds can be described as a simple series of "clicks", "buzzes", "zips" or "metallic whines". There are only a few other sounds heard in the park that might be mistaken as being produced by insects. Port Lincoln Ringneck parrots (*Barnardius zonarius*) produce series of clicks while feeding in the tops of trees that are similar to the sounds of certain katydids. The three frog species that occur in the park produce sounds that are very different from those produced by the park's insects: the moaning frog (*Heleioporus eyrei*) produces a long low moaning call; the turtle frog (*Myobatrachus gouldii*), a woodland burrowing species that calls with a series of barking croaks; and the banjo frog (or 'pobblebonk', *Lymnodynastes dorsalis*), found only in the ponds of the Botanical Gardens, produces a "bonk-bonk" call resembling the plucking of a banjo string (Main, 1965). Finally, the last sound which may be mistaken for that of an insect is the sound produced by the reticulation system, such as that which waters the Broadway Vista and Arboretum areas of King's Park. The modulated spray from these sprinklers produces a sound that is remarkably close to the call of one of the woodland cicadas!

A number of different terms will be used to describe the calls of the different singing insects. Many of the terms are onomatopoeic. Songs can be divided into two main groups. Pure-tone sounds are narrow in pitch or frequency. In insects these sounds are often single tones like the sounds of a whistle. However, most insect sounds tend to be "broad-band" noisy songs. Many calls have bursts of sound that do not last for more than a second: ticks are clock-like sounds; clicks represent very brief ticks; chirps are short, cricket-like pure-tones; zips resemble a fingernail being drawn over a comb (a lisp is a rapid and high-pitched zip). Other songs are more continuous: buzzes are continuous noisy sounds; rattles are buzzes that are modulated in intensity ("machine-gun like" is also used in the keys); a trill is a continuous pure-tone song.

The best way to learn the singing insects in a particular area is to begin in Spring and make note of each new species as the season progresses. By the time the orchestra of different singers has reached its peak in mid summer many species will already be identified so the task of recognizing the various singers will be that much easier (Alexander et al., 1972). As mentioned above, a bat-detector is a very useful aid in locating calls containing ultrasound.

As the keys to the different singers show, most species can be identified by determining not just what the call sounds like, but also where the singer is located (grasses, bushes or trees?) and the time in the day or season (Figs. 3, 4, 5 and Table 2) it is singing. In order to confirm the identity of the singer, first compare its call to the song pattern figured for the species. The sound can then be used to track down the insect and the specimen compared to the descriptions and photographs of the different singers (Table 1 and Figs 7 to 35).

Figures 3 to 5 show the seasonal calling activity of the more common insects. Most species show a distinct seasonal pattern with just one burst of activity which probably represents a single generation per year. There appear to be several exceptions to this: *Mygalopsis marki* and *Conocephalus upoluensis* appear to have two generations per year and sing during the winter months (Lymbery, 1987). Both species are rare in the park yet very common elsewhere. A long-winged meadow katydid *C. upoluensis* (Fig. 10), as its common name suggests, is found in grassy areas, being especially common along the Swan River. The cone-headed katydid *M. marki* (Fig. 11) is common in coastal vegetation and in open Jarrah-*Banksia* woodland outside of Perth. The only area of the park in which this species has been heard is in the vegetation on the steep slopes of Mt. Eliza above Mounts Bay Road. A third species which can be heard singing all year is a listroscelidine, the garden katydid *Requena verticalis* (Fig. 21). It is not clear whether this species has more than one generation per year. Its seasonal activity (Fig. 3) suggests one generation with a long calling season. The few males that call on warm days during the winter months (not shown in the Fig. 3 nocturnal count) may be males that have survived from the previous summer. The soft lisping sounds of *R. verticalis* can also be heard in suburban gardens. Indeed, this species is very common in reticulated areas and is a common sight on the walls of houses in late summer. A singing moth *Syntonarcha iriastis* (see below) calls for much of the year (Fig. 4) so probably has more than one generation per year.

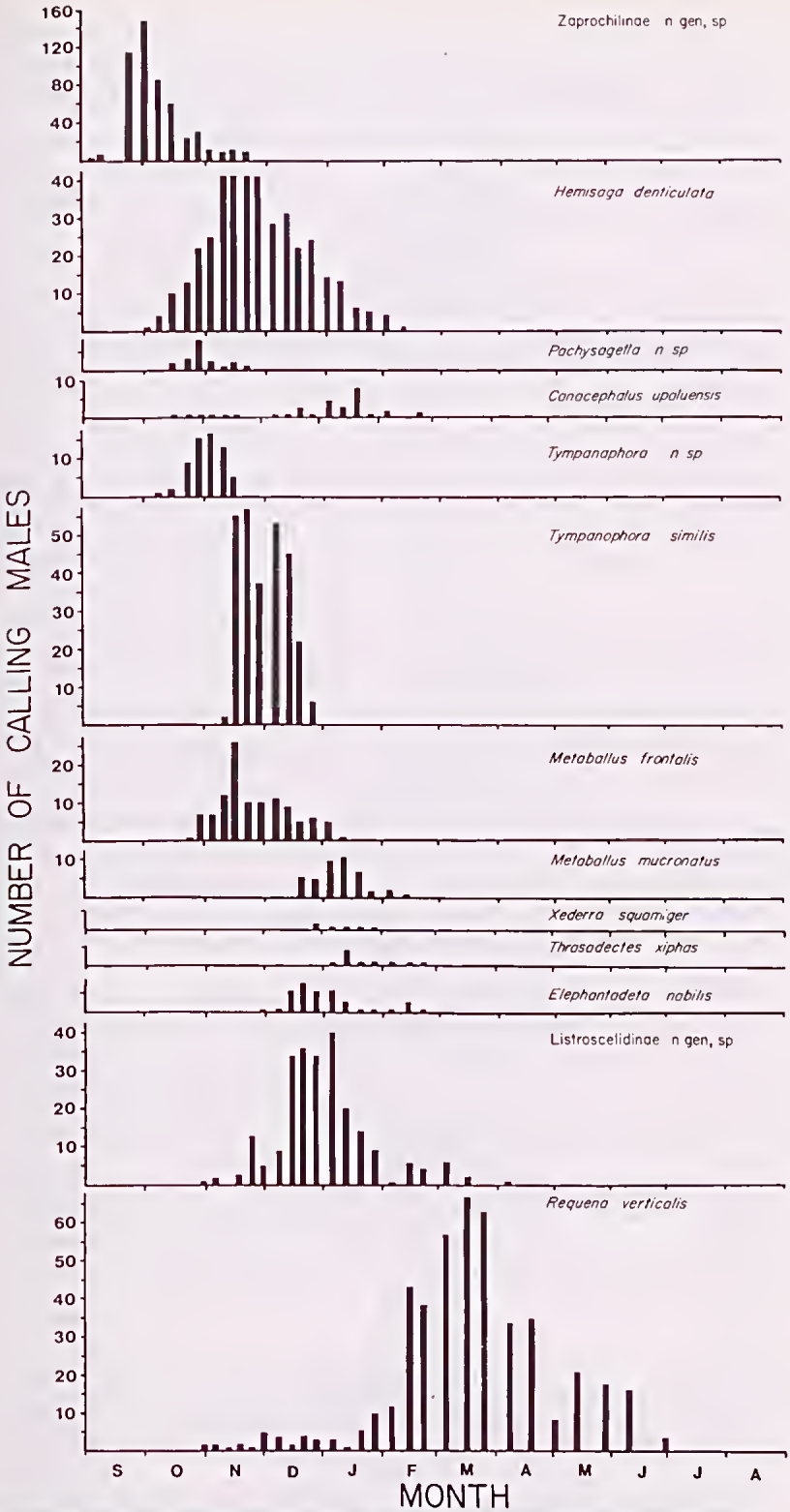

Figure 3: Nocturnal census of calling katydids (*Tettigonidae)* in King's Park, 1985-1986.

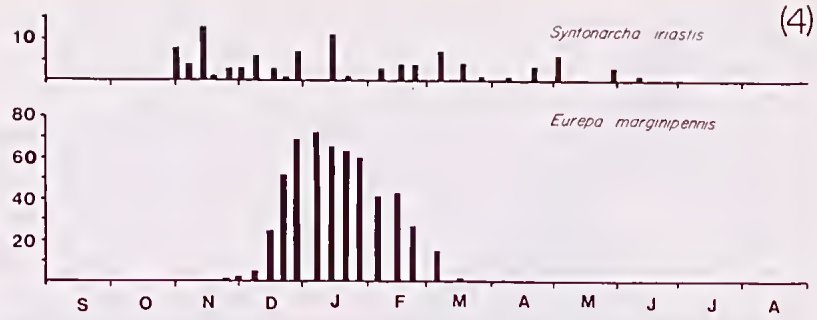

Figure 4: Nocturnal census of a cricket (*Gryllidae*) and moth in King's Park, 1985-1986.

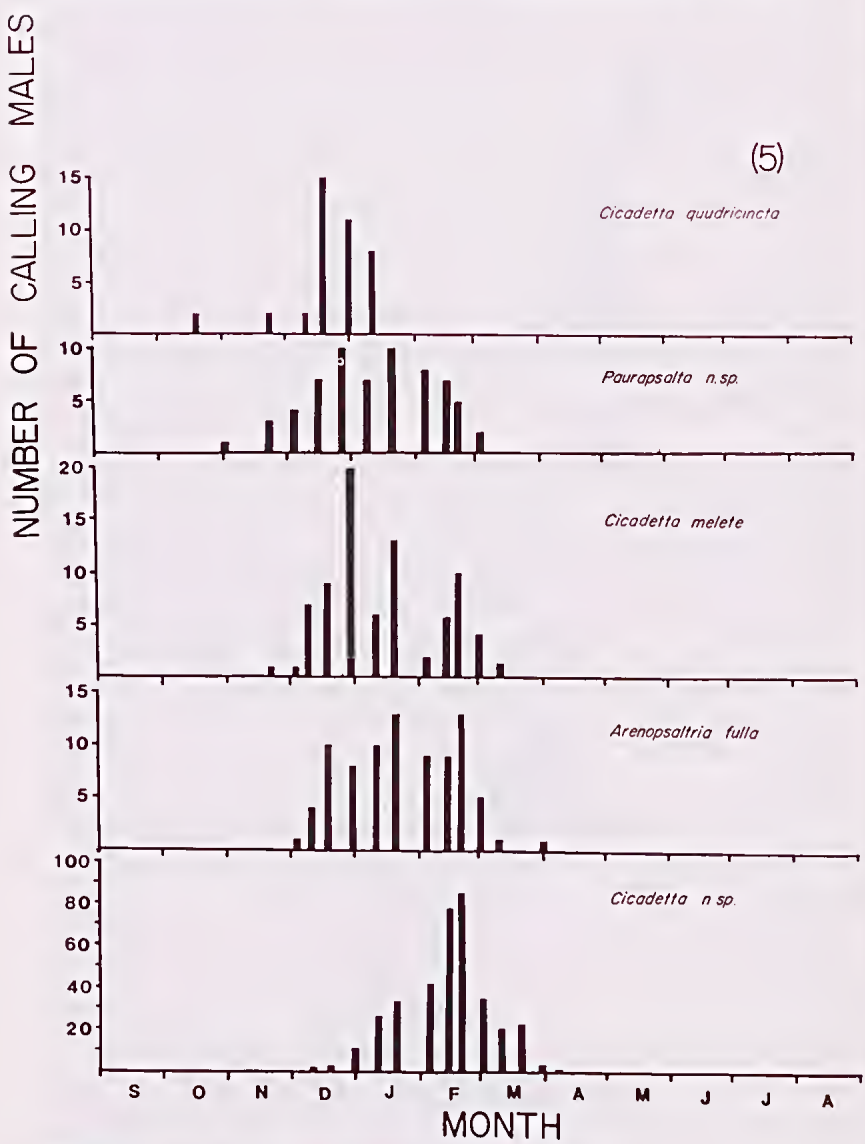

Figure 5: Diurnal census of calling cicadas in King's Park, 1986-1987.

Each of the remaining singing insects shows a distinct "calling season". The yearly schedule of singers in King's Park can be divided into two main parts. From mid spring to summer there is a nocturnal chorus dominated by singing katydids. The diversity of katydid singers shows a steep rise at the beginning of October and an equally sudden decline at the end of February (Fig. 6). The daytime chorus of singers during the hot months of summer is dominated by cicadas. The cicada season starts in mid-November and ends in March (Fig. 6).

The first of the seasonal singers is the most abundant of the singing insects, a short-winged and thin-bodied katydid (Fig. 7) which has turned out to be an unknown genus and species. Specimens are currently catalogued in the Australian National Insect Collection as Gen. nov. 22, sp. 1. This katydid produces a song at night that is completely inaudible to human ears as the sound energy is ultrasonic. Both this species and a stick-mimicking, non-acoustical katydid *Phasmodes ranatriformis* (Phasmodinae) are pollen and flower feeders. These insects appear to time their seasonal activities to coincide with the spring flowering of plants. They are especially common on the flowers of kangaroo paws (*Anigozanthos manglesii*) and blackboys.

The first audible katydid, heard in early October, is the very common *Hemisaga denticulata* (Saginae, Fig. 8). This species, the largest of the park's katydids, calls mainly from the tops of bushes during both night and day. Its loud zipping call dominates the singing insect chorus during most of katydid calling season. An undescribed species of *Pachysagella* (sp. 3) (Fig. 9) is a second sagine katydid active at this time of the year. It calls only at night from perches close to the ground.

A nocturnal katydid representing a new species of *Tympanophora* (Tympanophorinae) (Fig. 12) has a very short singing season of about four weeks, starting in mid-October. Its song consists of a 3-4 pulse chirp usually followed by a less intense "buzz" (Fig. 12). The activity of this species showed a sudden decrease in mid-November, at about the same time that its close relative *Tympanophora similis* (Fig. 13) begins its calling season which lasts about six weeks. Nightly censuses of the two species suggest that the song of *T. similis* may actually interfere with that of the new species (A. Schatral, unpublished). The very loud and distinct calling song of *T. similis* is the loudest of the singing insects during its brief calling season. Males of both species are very mobile (relative to other katydids), spending little time on each calling perch which is usually in bushes. Sexual dimorphism in *Tymanophora* is very pronounced; males have large "calling" forewings which envelop the abdomen whereas females are completely wingless (Figs. 12 and 13, compare top and bottom photographs).

Two species of long-winged katydids *Metaballus* also diverge temporally in their seasonal activity. Male *M. frontalis* (Fig. 14), first start calling in late October and are quite common in long grass, both in the park and in vacant lots and the edges of railway tracks in Perth. Two to three weeks before the decline in numbers of singers of this species the first *M. mucronatus* males begin calling.

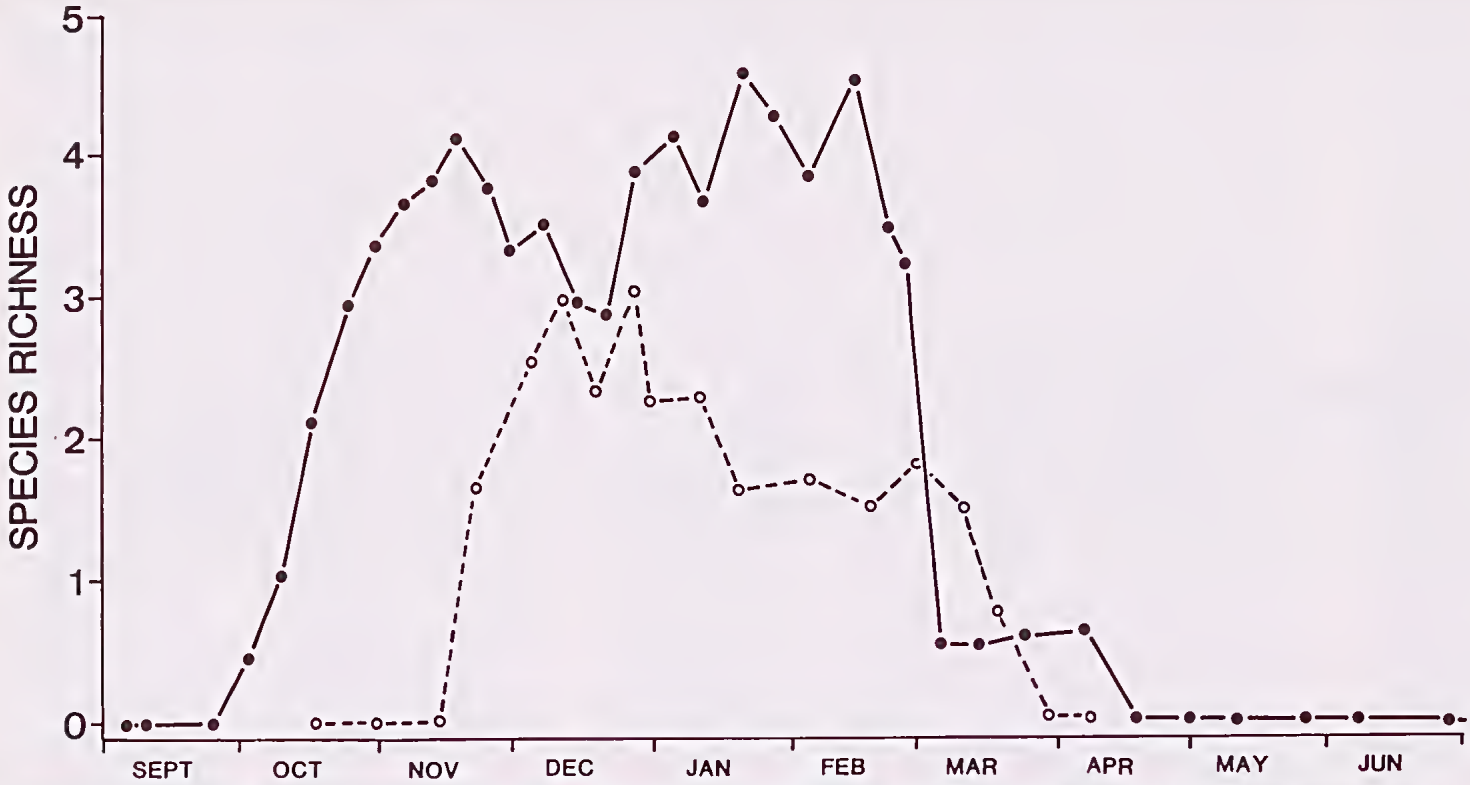

Figure 6: The species richness of the two main groups of calling insects in King's Park throughout the year. Solid line: katydids, broken line, cicadas. Data from Figures 3 and 4. The index of species richness was calculated using d = S-1/logN, where S = number of species and N = number of individuals (Simpson, 1949).

This species produces two different calls: its usual sound is a continuous buzzing song (Fig. 15) but occasionally males can be heard producing high-pitched "lisps" or "zips". Individuals often begin a calling session with a series of zips before changing to a continuous song. The two *Metaballus* species sing during both day and night and are the first and most common of the five species of tettigoniine katydids in the park, all of which call during spring and summer, mainly from singing perches in bushes. The remaining three species, *Xederra squamiger* (Fig. 16), *Throsodectes xiphos* (Fig. 17), and *Dexerra turpis* (Fig. 18) are strictly night singers. These three species are shield-backed katydids, named for the prominent thoracic pronotal shield from under which their small singing wings protrude. A bat detector is useful to pick up the sounds of these three species since much of the energy of their songs is in the ultrasonic range. Thus the calls are faint to the human ear. *T. xiphos* was not found in the park during 1984 and 1985. However, in the census (1986-87) this species was discovered to be quite common in regenerated heath-like vegetation in an area that suffered a bushfire in 1985.

Two nocturnal insects with purely ultrasonic songs begin to call in late October. An undescribed genus and species of listroscelidine katydid (Gen. nov. 9, sp. 1: Fig 20) resembles the other listroscelidine in the park, *Requena verticalis*, in coloration, body shape and the size of its singing wings. The continuous buzzy song of the ultrasonic katydid that is heard from the speaker of a bat detector is very similar to that of the other ultrasonic insect, males of a small pyralid moth, *Syntonarcha iriastis* (Figs. 20 and 34). However, the two species can be distinguished by their singing locations. The katydid has never been noted to sing more than half a metre above the ground whereas the singing perch of the moth is almost always in the tops of trees and bushes. The small ultrasonic moths can be spotted on their high singing perches by picking up their red, reflective eyes in torchlight. Calling male *S. iriastis* spread their wings slightly and curl the tip of the abdomen upward. The movement of the abdomen appears to engage a remarkable sound-producing structure consisting of a file located in the genitalia and a scraper on the eighth segment of the abdomen (Fig. 34, bottom) (Gwynne and Edwards, 1986).

The only species of false katydid (Phaneropterinae) heard in the park is the nocturnally-active *Elephantodeta nobilis* (Fig. 19). This species is one of the katydids in the park with functional flight wings. It sings from tall bushes and small trees and begins to produce its very complex clicking song in late November. Another false katydid which is known from the Perth area is *Torbia viridissima*. A single female of this species was collected in a Perth garden. The male song is unknown.

Three species of crickets (Gryllidae) sing in and around the park. The most common is the eneopterine *Eurepa marginipennis* (Fig. 23). This species is found in most parts of the park. Its pure-tone chirp can be heard in late afternoon and at night from late November to mid March. A second cricket (Fig. 24) is heard in late summer but appears to call only on a few nights. The frog-like "knee, knee, knee-deep" song of *Eurygryllodes* (subfamily Gryllinae) was common only on the few nights following late

summer rains in mid-March 1987. Unlike *Eurepa*, which always sing from vegetation, all the *Eurygryllodes* males observed were calling from the ground.

A cricket that has apparently been introduced to Australia from abroad is *Gryllodes sigillatus*, the decorated cricket (Fig. 25). The chirp of this species can be heard all year in and around houses and gardens in Perth. However, the closest this species appears to come to the native bush are the areas around buildings such as the university bordering the south side of the park. Likewise, neither of the two bush species has been heard in suburban gardens.

In autumn the song of a cricket that has also apparently been introduced to Western Australia can be heard on the grounds of the University adjacent to the park. *Ornebius aperta* (Fig. 26), a mogoplistine cricket, is very common in the flower beds around the Great Court, near the Reid Library of the University of W.A. Its song, a distinctive melodius chirp followed by a double chirp, has not been heard anywhere else in the Perth area. This species has apparently been introduced from southeastern Queensland, the locality from which the species was described and the only previously-known locality for this cricket (Otte and Alexander, 1983). In Queensland *O. aperta* was originally collected in rainforest underbrush. It appears to be thriving in the well-watered 'rainforest' of the Great Court area.

The onset of the calling season of cicadas heralds the beginning of summer. Four species, *Arenopsaltria fullo,* a new species of *Pauropsalta, Cicadetta quadricincta,* and *C. melete* show similar calling seasons with a dramatic increase in the activity of calling males during December (Fig. 5). The fifth species, an undescribed species of *Cicadetta*, begins calling at the end of December. Cicadas are very active during the warmest part of the day as evidenced by the loud chorus of males at midday. Cicadas almost always sing during daylight (the exception being *C. quadricincta* which calls on very warm evenings).

Cicadetta quadricincta (Fig. 30), the tick tock cicada, is named for its song and is the first cicada to call (in October). This species, like the garden katydid *R. verticalis* is very common in well-watered Perth gardens, its ticking song being a familiar mid-summer sound. However, whereas *R. verticalis* is found in the native bush of the park, *C. quadricincta* is restricted to watered areas such as the Botanical Gardens and the King's Park Tennis Club. The original habitat of this species may have been in vegetation close to water as they are common in native vegetation along creek margins (Moulds, in press) and on beaches. Male tick tocks call from bushes no higher than a couple of metres above the ground. They usually sing from one perch for about a half a minute before flying to the next calling site. At the end of the calling bout the song changes from a steady "tick-tock" so that the ticks are produced in pairs (see Fig. 30). The frequent movements of male tick-tocks allow them to cover large areas listening for the answering sounds of receptive females (Gwynne, 1987).

The clear "buzz-buzz" sound of *Pauropsalta* n. sp. males is first heard from bushes in early November (Fig. 33). This small species

is restricted in its distribution to only certain areas in the park. Only two to three small aggregations of calling males were heard on the census route.

The remaining three cicadas usually call from trees. The very loud sounds of the large-bodied sandgrinder *A. fullo* (Fig. 29) resemble the sound of a knife being sharpened on a rotating stone. Calling males, which perch on trees and in the tops of small trees, are well-spaced in the park.

Cicadetta melete, the red bandit cicada (Fig. 31) is named for the reddish-orange stripe across its abdomen. It calls mainly from the tops of taller trees such as *Eucalyptus* so it tends to be rare in the natural bush where tall gum trees are not widespread. Calling males are, however, common in the tops of trees which border the roads of the park. This insect can occasionally be heard calling from trees in suburban gardens. The species is very common in peppermint trees (*Agonis flexuosa*) in the Busselton area of Western Australia.

In late summer the undescribed *Cicadetta* species (Fig. 32) is the most abundant cicada in the park, reaching much greater densities than any of the other species (Fig. 5). Males call mainly from the tops of the smaller trees such as *Casuarina* and *Banksia*. The call of this cicada and the rate at which it is produced is very similar to the modulated spray of the system that is used to irrigate the lawn areas of the park!

The three *Cicadetta* species call at the same time of day and season but interactions between sexually-active adults of different species would probably be few given the distinct differences in the locations of calling males and in their song patterns.

By mid Autumn (late March) most of the year's insect instrumentalists have gone. At this time of the year the only remaining daytime singers are the katydid *Requena verticalis*, the last few tree-top *Cicadetta*, and the rapid clicks of male long-headed grasshoppers, *Acrida conica* (Fig. 27). Males of this species are smaller and more slender than the robust-bodied females. The clicking song is produced while flying just above the vegetation in open grassy areas. This display, called a "crepitation" flight, can be observed in a number of grasshopper species and probably attracts females.

A few singers can be heard throughout the winter months. As already mentioned, some katydids, particularly *R. verticalis*, sing on warm winter days. Wintertime is also the only season for two species whose soft rustling sounds are produced from perches near the ground. Males of a non-insect singer, a jumping spider (Salticidae: *Saitis michaelseni*) produce sound by rubbing stiff hairs on the front of the abdomen over a large file on the rear of the cephalothorax (Fig. 35). The sound does not appear to function in attracting females to males but instead is a part of the spider's courtship display (Gwynne and Dadour, 1985) (Fig. 35). Most of the reproductive activity takes place on the large stiff fallen leaves beneath *Banksia grandis* trees. The leaves may well aid in amplifying male sounds.

The last of the year's insect instrumentalists include a small grasshopper, *Heteropternis obscurella* (Fig. 28), and the third sagine katydid in the park, *Psacodonotus seriatus* (Fig. 22). Both produce faint calls. *H. obscurella* is a common species and produces a soft rustling calling song from open, sunny areas in late winter. The sagine katydid appears to be more rare. Although several individuals were heard in late winter, a single specimen was collected in summer. Thus, this species may have a long calling season.

KEYS FOR IDENTIFYING THE INSECT SONGS HEARD IN KING'S PARK[2]

Day singers

1a. A metallic/machinery-like sound 2
1b. Song not machinery-like, but consisting of zips, rattles, buzzes or ticks 3
2a. Loud, continuous "scissors grinding" machinery-like sound from trees, several metres above ground, from Oct. to Mar. ..... Sand Grinder Cicada, *Arenopsaltria fullo*
2b. Song not continuous; a steady "buzz-buzz" sound, with a vibrato-like modulation of intensity; from bushes ½ to 2 metres above ground, Nov. to Mar. .... Cicada, *Pauropsalta,* new species, 16M
3a. A series of ticks or chirps, 1-5 per sec. 4
3b. A series of buzzes, rattles, lisps, zips or rapid clicks 6
4a. Sings from tree tops, at least 3 metres above ground 5
4b. Song a series of clock-like "ticks", 2-3 per sec., from grasses and bushes, usually within 2 metres of ground, only in watered areas (common in gardens) late Oct. to early Feb. ..... Tick-tock Cicada, *Cicadetta quadricincta*
5a. A series of slow chirps (about 1 per sec.), each chirp not as sharp or tick-like as in other *Cicadetta* species, mainly from the tops of trees bordering park roads, Nov. to early Mar. ..... Red Bandit Cicada, *Cicadetta melete*
5b. Song a series of rapid ticks, 4-5 per sec., from the tops of *Banksia* or *Casuarina* trees, Jan. to early Apr. .... Cicada, *Cicadetta* new species
6a. A series of zips, lisps or rapid clicks, always with gaps of at least one sec. between bouts of sound-production 7
6b. A more-or-less continuous rattling or buzzing song with no long gaps between sound units (complete songs) 12
7a. A series of 8-9 loud clicks lasting less than a second, produced in open grassy areas by a flying insect .... Long headed grasshopper, *Acrida conica*
7b. A series of lisps or zips or soft rustling sounds 8
8a. Loud zips or lisps from vegetation 9
8b. Soft rustling, clicks or ticks 10
9a. Loud zips usually from bushes, each zip about 0.5 sec in length repeated every 1-2 secs, Oct-Feb. .... Katydid *Hemisaga denticulata*

[2]See above for descriptions of sounds used in reference to insect calls.

9b. Lisping zips, usually from grassy areas, Dec-Feb ..... Katydid, *Metaballus mucronatus*

10a. Soft rustling sounds from near the ground 11

10b. Song consists of four to six pulses each sec with each song separated by 1-3 sec ..... *Psacodonotus seriatus*

11a. Brief sounds produced every 5-7 secs or in longer bouts, 4-8 secs in length, every 30 secs from fallen leaves beneath trees; July-August ..... Jumping spiders, *Saitis michaelseni*

11b. Song from bare areas of ground in open sun and consisting of groups of four pulses per sec; winter to early spring ..... Grasshopper, *Heteropternis obscurella*

12a. A continuous loud rattling song 13

12b. A soft buzz or rattle 14

13a. A steady machine-gun-like rattle, Oct-Jan ..... Katydid, *Metaballus frontalis*

13b. Calling song consisting of groups of four pulses per sec with a very short delay between groups, Dec-Feb ..... Katydid, *Metaballus mucronatus*

14a. A high-pitched series of buzzes often interspersed with ticks, in grassy areas ..... Meadow katydid, *Conocephalus upoluensis*

14b. A series of lisping chirps, 4-6 per sec, all year but most common in summer ..... Garden katydid, *Requena verticalis*

Night Singers

1a. Song ultrasonic, any audible components not discernable from more than one metre away (usually detectable only with a bat detector) 2

1b. Song audible from at least 2 metres distant 6

2a. A continuous ultrasonic buzz with no obvious change in intensity 3

2b. Ultrasonic signal a continuous song with a machine-gun like modulation of intensity or a series of rapid clicks 4

3a. Signal almost always produced from the tops of trees and bushes, Oct-Jun ..... Pyralid moth, *Syntonarcha iriastis*

3b. Signal from grasses and shrubs, never more than 1 metre above the ground, Oct-Apr ..... Listroscelidine katydid (undescribed genus and species)

4a. Signal with machine-gun-like modulation of intensity, Dec-Jan ..... Shield-backed katydid, *Xederra squamiger*

4b. Signal a series of rapid clicks 5

5a. Common from late Aug. to Nov ..... Zaprochiline katydid (undescribed genus and species)

5b. Rare, Jan. to Mar ..... Shield-backed katydid, *Dexerra turpis*

6a. Song with at least some pure-tone components (with a narrow carrier frequency) 7

6b. Song noisy with no pure-tone components (i.e. with a broad carrier frequency; consisting entirely of buzzes, clicks or zips) 12

7a. A cricket-like pure-tone chirping or trilling song 8

7b. A complex song with both pure-tone and buzzing (noisy) components 11

8a. Song a simple, continuous pure-tone trill, late Nov. to March, from vegetation ..... Cricket, *Eurepa marginipennis*

8b. Song broken into distinct chirps, from near ground 9
9a. In bushland, chirps produced at about two per sec, late summer ..... Cricket, *Eurygryllodes sp.*
9b. Not in bushland 10
10a. In and around buildings, chirps produced at 5-10 per sec, all year ..... Decorated cricket, *Gryllodes sigillatus*
10b. In flowerbeds on the University of W.A. campus; song a single chirp followed by a double chirp and produced about 1 per sec ..... *Ornebius aperta*
11a. Song consisting of a 3-pulse ringing, chirp, 1-2 sec in length usually repeated every 2-3 sec, with each chirp usually followed by a separate but distinct short buzz, Oct.-Nov ..... Katydid, *Tympanophora,* new species
11b. Song very loud: either a series of steady ringing chirps 2-3 per sec (each chirp resembling a hammer striking an anvil) or a series of repeated songs with each song some 10 sec in length consisting of 10-12 ringing chirps at 2-3 per sec. followed by a complex series of rapid chirps for about 2 sec., Nov.-Dec ..... Katydid, *Tympanophora similis*
12a. Song broken into a series of "zip"-like sounds 13
12b. Song at least in part consisting of a noisy buzz or rattle ... 15
13a. Song a series of 4-5 double zips with 10 or more secs between songs Oct-Nov .... Katydid, *Pachysagella,* new species
13b. Song a series of loud single zips each about 1 sec in length and repeated every 1-2 secs 14
14a. Slow, loud zip much like a fingernail being drawn quickly over the teeth of a comb, Oct-Feb .... Katydid, *Hemisaga denticulata*
14b. Faster zip and usually changing into a continuous "galloping" song ..... Katydid, *Metaballus mucronatus*
15a. Song loud, audible from 5 or more metres away 16
15b. Song soft, usually audible 1-5 metres away 20
16a. Each song very complex and consisting of several sounds of very distinct buzzes, rattles and clicks with the song being repeated in the same sequence, late Nov to Feb ..... Katydid, *Elephantodeta nobilis*
16b. A simple buzzing, rattling or chirping song 17
17a. Calling song a series of evenly spaced, loud "chirrups", each about two secs in length, calls all year (only heard on the slope of Mt. Eliza) .... Cone-headed katydid, *Mygalopsis marki*
17b. A rattling or lisping song with a machine-gun like modulation of intensity 18
18a. A loud, continuous rattling song 19
18b. A series of lisping rattles, usually 2-6 per sec, from low in bushes ..... Garden katydid, *Requena verticalis*
19a. Calling song a steady machine-gun like rattle, not divided into pulses grouped into fours, Oct-Dec .... Katydid, *Metaballus frontalis*
19b. Calling song consisting of groups of four pulses per sec with a very short delay between groups, Dec.-Feb .... Katydid, *Metaballus mucronatus*

20a. Song a repeated high-pitched buzz often followed by ticks, from grasses, all year .... Meadow katydid, *Conocephalus upoluensis*

20b. Song a continuous series of pulses grouped into fours with a brief delay between groups, Jan-Feb .... Shield-backed katydid, *Throsodectes xiphos*

KEYS FOR IDENTIFYING INSECT SONGS HEARD IN PERTH GARDENS

1a. Song a continuous noisy buzz 2

1b. Song a series of noisy or pure-tone chirps or clicks 4

2a. A repeated high-pitched buzz, often followed by ticks from long grasses, particularly near rivers and lakes .... Meadow katydid, *Conocephalus upoluensis*

2b. Song with a machine-gun like modulation of intensity 3

3a. A series of lisping rattles, usually 2 to 6 per sec. in gardens, all year but very common in Autumn .... Garden katydid, *Requena verticalis*

3b. A loud rattle, rare in gardens but common in long grasses along roadsides, railway lines etc. in Summer .... Katydid, *Metaballus frontalis*

4a. Song a series of pure-tone chirps, crickets 5

4b. Song a series of ticks, tocks or clicks 6

5a. A series of rapid chirps, common in and around buildings, all year ..... Decorated cricket, *Gryllodes sigillatus*

5b. A sequence repeated about once per sec, consisting of a single chirp, followed by a double chirp. Only in flower beds of the University of W.A. campus .... Cricket, *Ornebius aperta*

6a. A series of regular ticks, 1-3 per sec, cicadas 7

6b. A series of 8-9 clicks produced in under a sec; produced while in flight in open, sunny areas, occasionaly in gardens ..... Long-headed grasshopper, *Acrida conica*

7a. A series of ticks, 2-3 per sec. up to about 3 metres above ground common in gardens in summer .... Tick tock cicada, *Cicadetta quadricincta*

7b. A series of ticks, 1 per sec, usually from treetops above 3 metres, in summer ..... Red bandit cicada, *Cicadetta melete*

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REFERENCES CITED

ALEXANDER, R.D. 1960. Sound communication in Orthoptera and Cicadidae. Pp. 38-92, in, W.E. Lanyon and W.N. Tovolga, Eds.). *Animal Sounds and Communication*. Publ. # 7, AIBS, Washington.

ALEXANDER, R.D. 1967. Acoustical communication by Arthropods. *Ann. Rev. Entomol.* 12: 495-526.

ALEXANDER, R.D., A.E. PACE and D. OTTE. 1972. The singing insects of Michigan. *Great Lakes Entomol.* 5: 33-69.

ALLARD, H.A. 1929. Our insect instrumentalists and their musical technique. *Ann. Rept. Smithson. Instit.* for 1928: 563-591.

BRUNELLI, cited in Russell et. al (1831).
CHAPMAN, R. 1982. *Insects: Structure and Function*. Hodder and Stoughton, London.
GWYNNE, D.T. 1987. Sex-biased predation and the risky mate-locating tactics of male tick-tock cicadas. *Anim. Behav.*, 35: 571-576.
GWYNNE, D.T. and I.R. DADOUR. 1985. A new mechanism of sound production by courting male jumping spiders (Araneae: Salticidae, *Saitis michaelseni* Simon). *J. Zool.* 207: 35-42.
GWYNNE, D.T. and E.D. EDWARDS. 1986. Ultrasound production by genital stridulation in *Syntonarcha iriastis* (Lepidoptera: Pyralidae): long-distance signalling by male moths? *Zool. J. Linn. Soc.* 88: 363-376.
LYMBERY, A. 1987. Seasonal populations in the life cycle of *Mygalopsis marki* (Orthoptera: Tettigoniidae). *J. Austr. Entomol. Soc.* 26: 323-330.
MAIN, A.R. 1965. *Frogs of southern western Australia*. Handbook No. 8, West. Austr. Nat. Club, Perth.
MAIN, A.R. and M.A. CARRIGY. 1953. Native snails of the genus *Bothriembryon* in King's Park, Perth. *West. Austr. Nat.* 4: 49-59.
MAIN, A.R., D.L. SERVENTY et al. 1957. King's Park as an indigenous park: a natural history approach. *West. Austr. Nat.* 6: 25-53.
MOULDS, M.S. (in press). *A Guide to the Australian Cicadas*. New South Wales Press, Kensington.
OTTE, D. 1977. Communication in Orthoptera. Pp. 334-361, in, T.A. Sebeok (ed.), *How Animals Communicate*. Indiana University Press, Bloomington.
OTTE, D. and R.D. ALEXANDER. 1983. *The Australian Crickets* (Orthoptera: Gryllidae). Acad. Nat. Sciences, Philadelphia. Monograph 22.
PRINGLE, J.W.S. 1954. A physiological analysis of cicada song. *J. Exp. Biol.* 31: 525-560.
RUSSELL, Lord John et al (committee) 1831. *Insect Miscellanies*. Charles Knight, London.
SIMPSON, E.H. 1949. Measurement of diversity. *Nature* 163:688.
TINGAY, A. and S. TINGAY. 1982. *Common Animals in Kings Park and Perth Gardens*. Kings Park Board, Perth.
WALKER, T.J. 1974. Character displacement in acoustical insects *Amer. Zool.* 14: 1137-1150.
WEST EBERHARD, M.J. 1984. Sexual selection, competitive communication and species-specific signals in insects. Pp. 283-324, in, T. Lewis (ed). *Insect Communication*. Academic Press, London.

Table 1. A Systematic List of the singing insects of King's Park and Perth.

INSECTA

Order: ORTHOPTERA
Family: **Tettigonildae (katydids)**
Subfamily: Phaneropterinae (false katydids)
Elephantodeta nobilis Walker
Torbia viridissima Brunner

Subfamily: Zaprochilinae (ultrasonic katydids)
Genus Nov. 22 sp. # 1
Subfamily: Phasmodinae (stick katydids)
Phasmodes ranatriformis Westwood[3]
Subfamily: Tympanophorinae
Tympanophora similis Riek
Tympanophora n. sp. (near splendida)
Subfamily: Listroscelidinae
Requena verticalis Walker
Genus Nov. 9, sp. # 1.
Subfamily: Conocephalinae (meadow and coneheaded katydids)
Conocephalus upoluensis (Karny)
Mygalopsis marki Bailey
Subfamily: Saginae
Hemisaga denticulata White
Pachysagella n. sp. # 3
Psacadonotus seriatus Redtenbacher
Subfamily: Tettigoniinae (shield-backed katydids)
Metaballus frontalis (Walker)
Metaballus mucronatus Rentz
Xederra squamiger Ander
Throsodectes xiphos Rentz
Dexerra turpis Walker
Family: **Gryllidae (crickets)**
Subfamily: Eneopterinae ("bush" crickets)
Eurepa marginipennis (White)
Subfamily: Gryllinae (field and house crickets)
Eurygryllodes sp. (in the *warilla* group)
Gryllodes sigillatus (Walker)
Subfamily: Mogoplistinae (short-winged crickets)
Ornebius aperta Otte and Alexander
Family: **Acrididae (grasshoppers and locusts)**
Subfamily: Acridinae (slant-faced grasshoppers)
Acrida conica (Fabricius)
Heteropternis obscurella (Blanchard)

Order: HEMIPTERA
Family: **Cicadidae (cicadas)**
Subfamily: Cicadinae
Arenopsaltria fullo (Walker) Sand grinder
Subfamily: Tibiceninae
Cicadetta quadricincta (Walker) Tick tock
Cicadetta melete (Walker) Red bandit
Cicadetta n. sp. # 75M (near *latoria*)
Pauropsalta n. sp. # 16M (near *encaustica*)

Order: LEPIDOPTERA
Family: **Pyralidae**
Syntonarcha iriastis Meyrick

ARACHNIDA

Order: ARANEAE
Family: **Salticidae (jumping spiders)**
Saitis michaelseni Simon

[3]Males of this species do not produce sounds; it is included here to complete the list of katydids found in the King's Park area.

Table 2. Identification of singing katydids, crickets, grasshoppers and cicadas using specimens, location and time of calling activity.

Species	Figure	Specimen Description	Location	Singing Time
ORTHOPTERA		Enlarged jumping hind legs; no beak-like mouth parts; wings opaque or translucent		
Ensifera (katydids & crickets)		Antennae longer than body		
Tettigoniidae (katydids)		Tarsi 4-segmented; wings held close to body when singing; no long tail filaments (cerci)		
Zaprochilinae sp.	7	Body length ca. 2.2 cm; very slender and stick-like	In low grasses and shrubs	Night, Aug to Nov
Hemisaga denticulata	8	Large, body length ca. 4 4 cm; green with white stripes along body sides; wings cover half of abdomen.	Tops of bushes and small trees	Day and night, Oct to Feb
Pachysagalla n. sp.	9	Large, body length ca. 3.2 cm; short and fat; grey/brown with white markings; wings cover a third of abdomen.	On ground or low shrubs	Night, Oct-Nov
Conocaphalus upoluensis	10	Body length ca. 1.7 cm; green or brown; wings longer than abdomen	In grasses	Day and night, all year
Mygalopsis marki	11	Body length ca. 2.8 cm; green or brown, with a long "unicorn-like" horn between eyes	In shrubs and bushes	Night, all year
Tympanophora n. sp.	12	Length from head to wingtip ca. 2.7 cm; green; wings longer than body, and differ from *similis* in being rounded at tip; female wingless and brown	In shrubs and bushes	Night, Oct to Nov
Tympanophora similis	13	Length from head to wing tip ca. 3 4 cm; green; wings longer than body but differ from the new species in being pointed at the tip; female wingless and green.	In shrubs and bushes	Night, Nov to Dec
Metaballus frontalis	14	Green; body length ca 3 cm; white stripe on sides of pronotal shield (behind head) dips into "u" shape; vertical white markings on forewings.	In grasses and bushes	Day and night, Oct to Jan
Mataballus mucronatus	15	Body length ca. 3 cm; differs from *frontalis* in having more-or-less straight pronotal shield stripes. Tan markings on forewings.	In grasses and bushes	Day and night, Dec to Mar
Xedarra squamigar	16	Body length ca. 2.2 cm; very long jumping legs; wings cover a third of abdomen; differs from *T. xiphos* in that the white borders of pronotal shield, if present, are narrow; grey to brown	In shrubs and bushes	Night, Dec to Feb
Throsodactas xiphos	17	Body length ca. 1.7 cm; very long jumping legs; wings cover half of abdomen; differ from *X. squamiger* in that the white pronotal border forms "m" shape and wings cover half of abdomen with the overlap forming a deep "v"; red-brown.	In shrubs and bushes	Night, Jan to March
Daxarra turpis	18	Small, about 1 cm in length; short-winged species; brown with no markings; distinct pronotal shield.	Shrubs and bushes	Day and night, Jan to Mar
Elaphantodata nobilis	19	Head to wingtip ca. 5 cm; wings longer than abdomen; green with rounded head.	Tops of bushes and small trees	Night, Nov to Feb
Listroscelidina, n. sp.	20	Body length ca. 1.6 cm; very short wings; dorsal black stripe running from head to wings; colour, brown with red tip to abdomen.	In shrubs, close to ground	Night, Nov to Apr
Raquana varticalis	21	Body length ca. 2.2 cm; very short wings; brown with a pronounced pronotal shield	In shrubs and bushes	Day and night, mainly Dec to Jun
Psacadonotus saniatus	22	Body length ca. 2.5 cm; wings (edged with green); grey brown with white stripes on face and on edge of pronotal shield.	In vegetation	Day, Aug to Dec
Gryllidae (crickets)		Tarsi, 3-segmented, wings held almost at right angles to body when singing; long pair of cercal filaments; brown with black markings.		

Eurepa marginipennis	23	Body length ca. 1.5 cm; wings more than twice as long as wide; cercal filaments as long as body	Low on leaves and tree trunks	Late afternoon-night, Nov to Apr
Eurgryllodes sp.	24	Body length ca. 1.1 cm; wings about 1.5 times as long as wide; cercal filaments half as long as body.	On ground	Rare; night, late summer (after rain)
Gryllodes sigillatus	25	Body length ca. 1.5 cm; wings just slightly longer than wide; cercal filaments ¾ as long as body.	On ground, near buildings	All year
Ornebius aperta	26	Small, body length 1 cm	Flower beds, U.W.A. campus	Autumn
Acrididae (grasshoppers)		Antennae shorter than body.		
Acrida conica	27	Body length ca. 5 cm; long and slender with long cylindrical head; wings longer than abdomen; brown to green.	In grasses and open areas	Day, Feb to June
Heteropternis obscurella	28	Body length ca. 2 cm; wings longer than body; brown with white markings including dorsal white stripe on pronotal shield.	On ground	Day, Late Winter
HEMIPTERA				
Cicadidae (cicadas)		All legs similar in size; wings transparent; mouthparts beak-like.		
Arenopsaltria fullo	29	Large, forewing length ca. 3.4 cm; black and brown with white stripe across top of abdomen	Trees	Day, Dec to Mar
Cicadetta quadricincta	30	Forewing length ca. 1.6 cm; black to brown.	Bushes and in watered areas	Day and warm nights, Oct-Jan
Cicadetta melete	31	Forewing length ca. 2.4 cm; black with orange stripe across top of abdomen.	Tops of trees; esp. gums	Day, Nov to Mar
Cicadetta n. sp.	32	Forewing length ca. 2.0 cm; black with no stripe on abdomen.	Tops of *Banksia* & *Casuarina*	Day, Dec to Apr
Pauropsalta n. sp.	33	Small, forewing length ca. 1.5 cm; black; has 5 cells at the tip of each hind wing, unlike *Cicadetta* spp. which have 6 cells.	Bushes and grasses	Day, Oct to Mar

Figures 7 to 35.

Photographs and calling patterns of the singing insects (as resolved by the human ear). Each song trace represents 4 seconds. The scale bars in the lower right corners represent 0.5 cm except for the micrographs of sound producing structures in figs 34-35 in which the bar represents 0.2 mm.

7 to 22: Katydids (Tettigoniidae).

The lower photographs in Figs. 12 and 13 are the females of each *Tympanophora* species. Fig. 19 shows a newly-mated female *Elephantodeta* carrying the large spermatophore (sperm package) at the tip of her abdomen. Figure 21 courtesy of A.G. Wells and Fig. 18 of D.C.F. Rentz.

23 to 26: Crickets (Gryllidae).

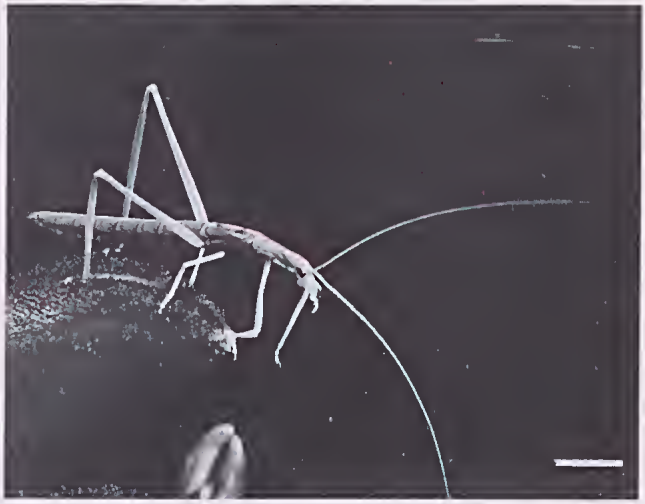
The males in Figs. 23 and 24 have their wings raised in the calling position. Song pattern in figure 25 redrawn from Otte and Alexander (1983).

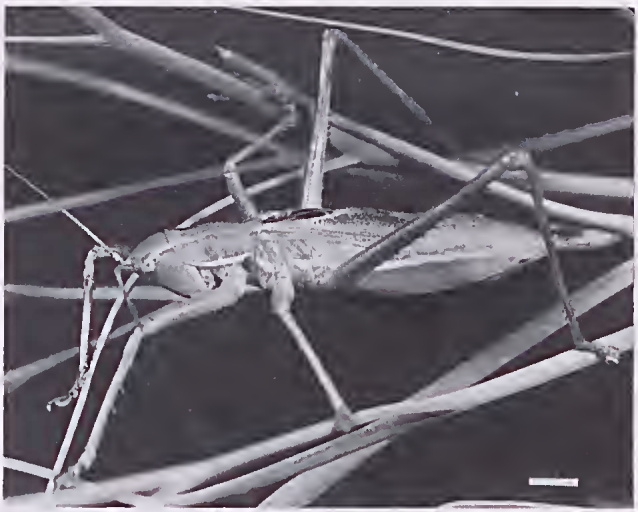
27 and 28: Grasshoppers (Acrididae).

29 to 33: Cicadas (Cicadidae).

34 and 35: Other singing insects.

The lower photograph of each figure shows the mechanism used for sound production in each species. For the moth, *Syntonarcha iriastis* (Fig. 34), the file (in the foreground of the figure) is part of the genitalia. For the spider, *Saitis michaelseni* the file (Fig. 35) is located on the dorsum of the rear part of the cephalothorax. Figure 34 from Gwynne and Dadour (1985) and figure 35 from Gwynne and Edwards (1986).





7

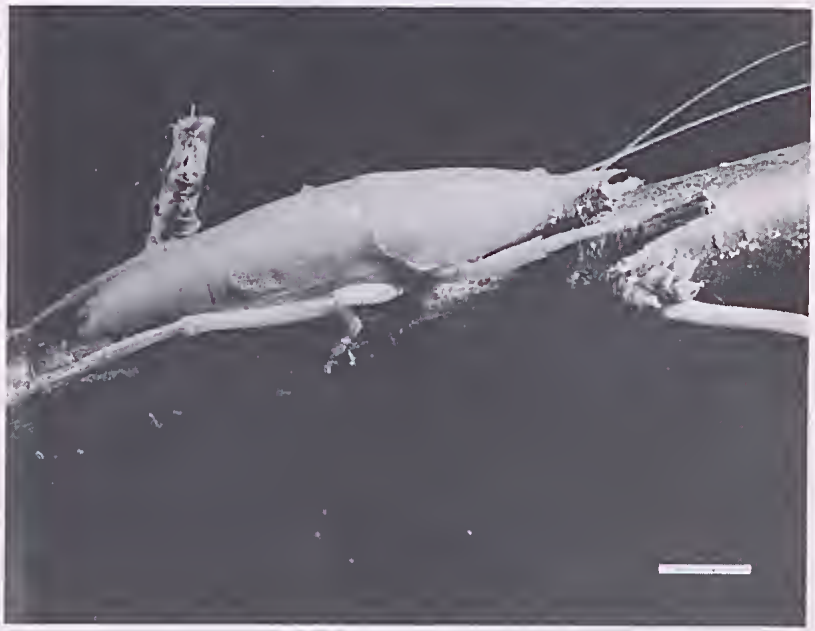
Zaprochilinae n. sp.

8

Hemisaga denticulata

9

Pachysagella n. sp.

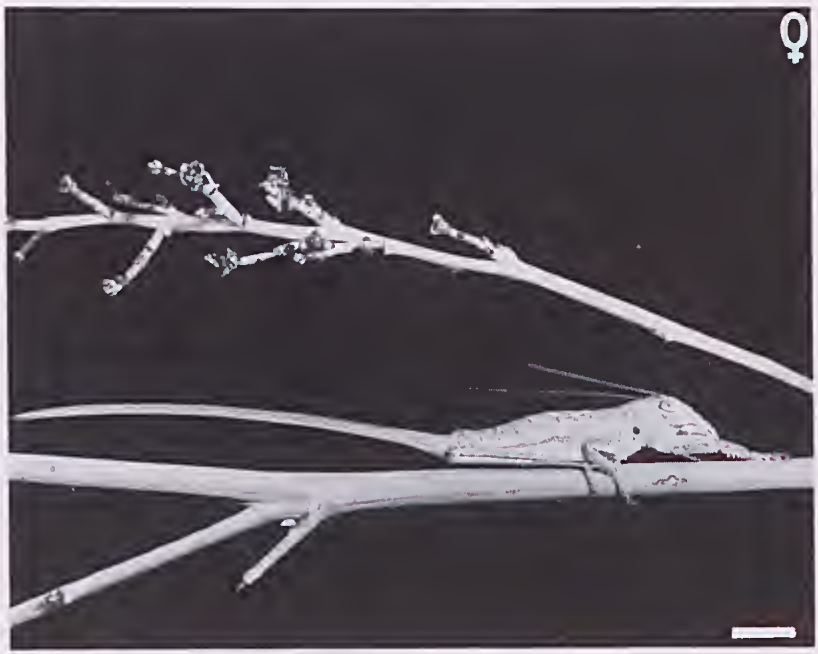


10

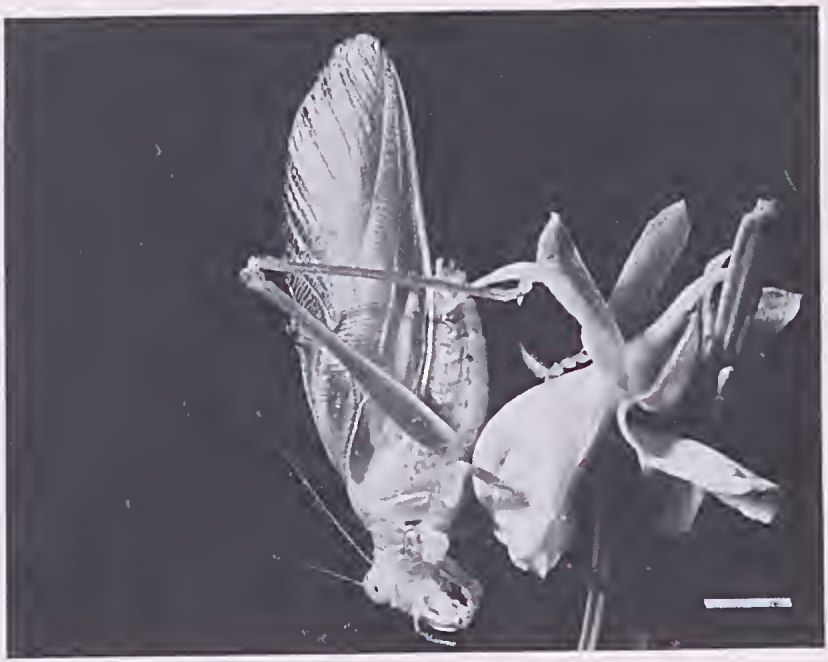
Conocephalus upoluensis

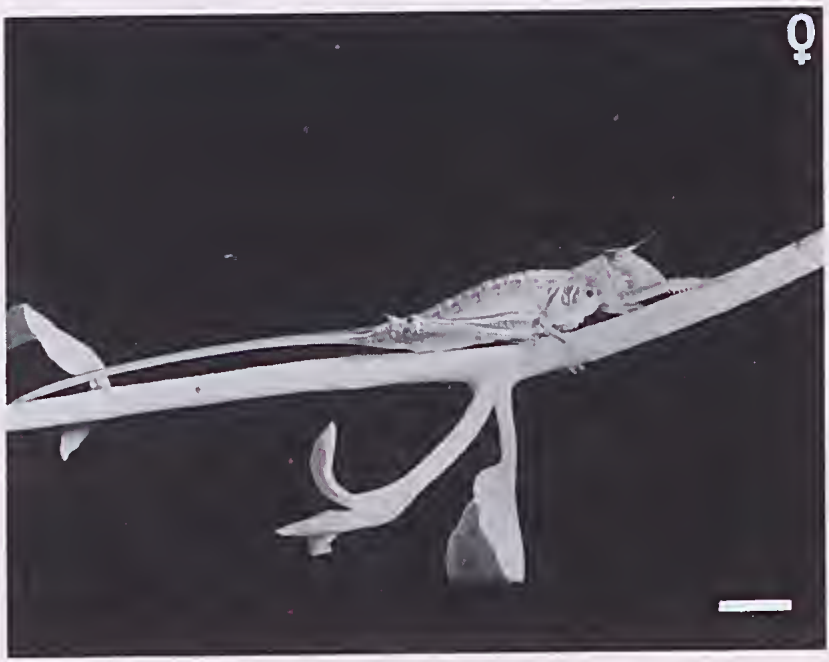
11

Mygalopsis marki



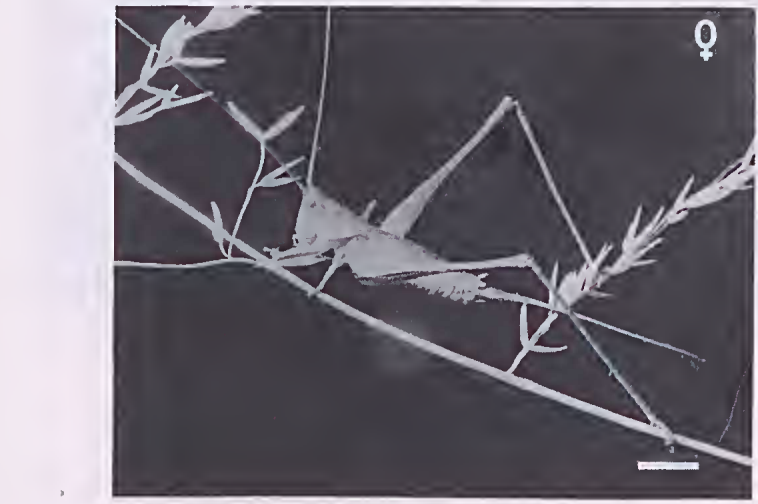
Tympanophora n. sp.





13

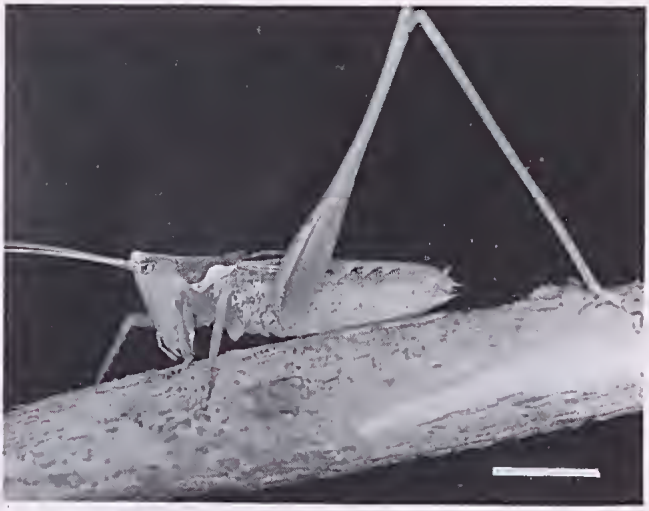
Tympanophora similis



Metaballus frontalis **14**

Metaballus mucronatus **15**

Xederra squamiger **16**



17

Throsodectes xiphos

18

Dexerra turpis

19

Elephantodeta nobilis

20

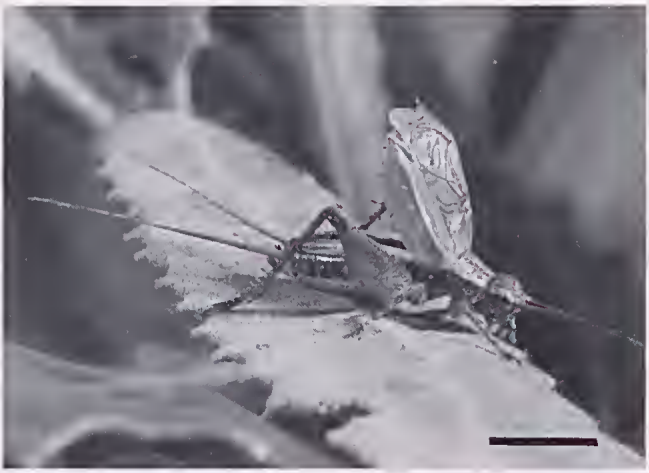
Listroscelidinae n. sp.

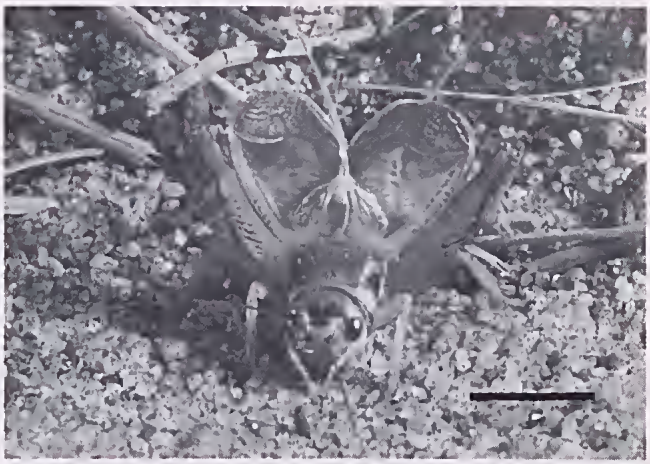
21

Requena verticalis

22

Psacadonotus seriatus





23

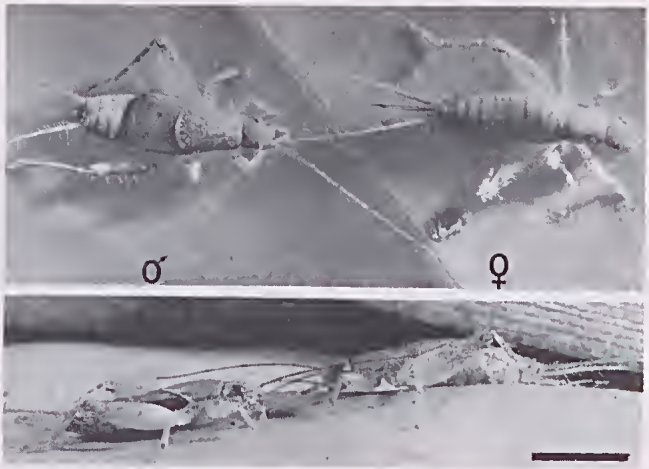
Eurepa marginipennis

24

Eurygryllodes

25

Gryllodes sigillatus



Grasshoppers (Acrididae)

26

Ornebius aperta

27

Acrida conica

28

Heteropternis obscurella

29

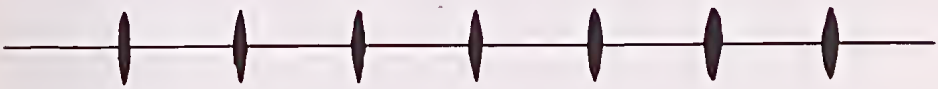
Arenocopsaltria fullo

30

Cicadetta quadricincta

31

Cicadetta melete



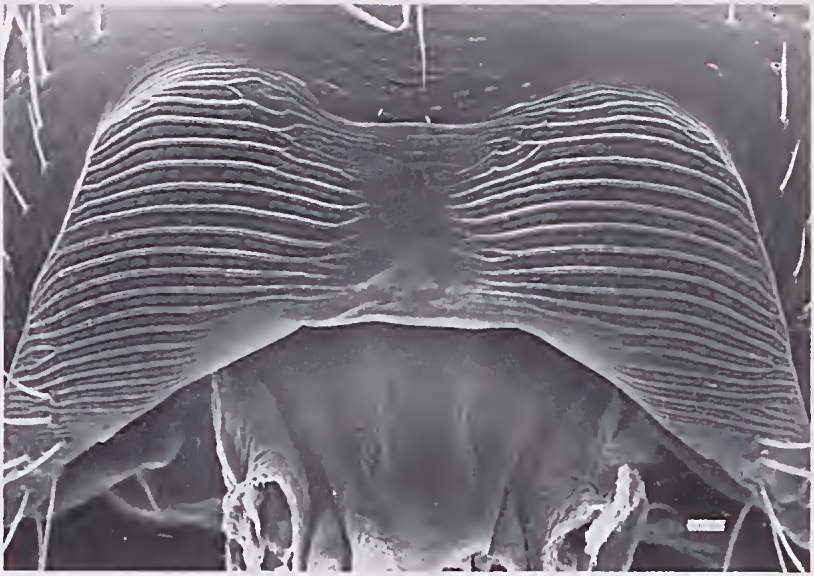
32

Cicadetta n. sp.

33

Pauropsalta n. sp.

Syntonarcha iriastis



Saitis michaelseni